Appendix A
ASP/CSP Examination Reference

UNIT CONVERSIONS

Length

1 in = 2.54 cm 1 ft = 30.48 cm

1 micron = 10^{-4} cm 1 angstrom = 10^{-4} cm

Volume

1 liter = 1.06 qt = 61.02 in^3 = 0.03531 ft^3

Mass

1 kg = 2.2 lbs 1 lb = 454 gm

Pressure

1 atm = 14.7 psi
= 760 mm Hg
= 29.92 in Hg
= 33.90 ft H_2O
= 760 torr
= 101.3 kPa

Temperature

$$t_{°C} = \frac{(t_{°F} - 32)}{1.8}$$

$t_{°K} = t_{°C} + 273$ $t_{°R} = t_{°F} + 460$

Radiation

1 rad = 10^{-2} gray

1 rem = 10^{-2} sievert

1 curie = 3.7×10^{10} becquerel

1 becquerel = 1 disintegration/sec

Density of Water

1 gm/cm^3 = 1.94 $slugs/ft^3$

(weight density = 62.4 lbs/ft^3)

Angles

$$1 \text{ radian} = \frac{180°}{\pi}$$

Light

1 candela = 1 lumen/steradian

1 footcandle = 10.76 candela/m^2 = 10.76 lux

Magnetic Fields

1 tesla = 10,000 gauss

Energy

1 British thermal unit = 1,055 joules

1 faraday = 9.65×10^4 coulombs

1 gm-calorie = 4.19 joules

1 gm-mole @ 0° C and 1 atm = 22.4 liters
@ 25° C and 1 atm = 24.45 liters

1 ampere-hour = 3,600 coulombs

1 watt = 1 joule/sec = 1 ampere x 1 volt

1 kwh = 3.6×10^6 joules

PHYSICAL CONSTANTS

acceleration of gravity = 32.2 ft/sec^2 = 9.8 m/sec^2

velocity of light = 3.0×10^8 m/sec

Planck's constant = 6.626×10^{-34} J-sec

Avagadro's number = 6.024×10^{23}/ gm-mole

STANDARDS

STP (Physical Science) = 0° C and 1 atm

STP (Ventilation) = 70° F and 1 atm
air density = 0.075 lb/ft^3 @ 70° F and 1 atm

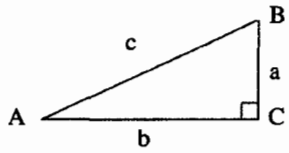
STP (Industrial Hygiene) = 25° C and 1 atm

TRIGONOMETRIC FUNCTIONS

$\sin A = a/c \qquad \cos A = b/c \qquad \tan A = a/b$

$c^2 = a^2 + b^2 - 2ab \cos C$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$



BOOLEAN POSTULATES

$A + B = B + A$	$A + 0 = A$
$A \cdot B = B \cdot A$	$A \cdot 1 = A$
$A(B \cdot C) = (A \cdot B)C$	$A + A' = 1$
$A + (B + C) = (A + B) + C$	$A \cdot A' = 0$
$A(B + C) = (A \cdot B) + (A \cdot C)$	$A \cdot A = A$
$A + (B \cdot C) = (A + B) \cdot (A + C)$	$A + A = A$

QUADRATIC EQUATION

$$x_1, x_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

MECHANICS

$F = \mu N$

$F_1 D_1 = F_2 D_2$

$v = v_0 + at$

$s = v_0 t + \frac{at^2}{2}$

$v^2 = v_0^2 + 2as$

$K.E. = \frac{mv^2}{2}$

$P.E. = mgh$

$P.E. = \frac{kx^2}{2}$

$p = mv$

$F = ma$

$W = mg$

$W = Fs$

ELECTRICITY

$R = \rho \frac{L}{A} \qquad V = IR \qquad P = VI$

$R_{series} = R_1 + R_2 + \cdots + R_n$

$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$

$\frac{1}{C_{series}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$

$C_{parallel} = C_1 + C_2 + \cdots + C_n$

$L_{series} = L_1 + L_2 + \cdots + L_n$

$\frac{1}{L_{parallel}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}$

ERGONOMICS (REVISED NIOSH LIFTING EQUATIONS)

RWL = LC x HM x VM x DM x AM x FM x CM

RWL (kg) = (23) (25 / H) [1 - (0.003 |V - 75|)] [0.82 + (4.5 / D)] (1 - 0.0032A) (FM) (CM)

RWL (lb) = (51) (10 / H) [1 - (0.0075 |V - 30|)] [0.82 + (1.8 / D)] (1 - 0.0032A) (FM) (CM)

$$LI = \frac{L}{RWL}$$

Coupling Type	Coupling Multiplier Table	
	V < 30 inches (75 cm)	V ≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Frequency Multiplier Table

Frequency Lifts/min.	Work Duration					
	≤ 1 Hour		>1 but ≤ 2 Hours		>2 but ≤ 8 Hours	
(F) ††	V < 30 †	V ≥ 30	V < 30	V ≥ 30	V < 30	V ≥ 30
≤0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.60	0.70	0.42	0.42	0.22	0.22
8	0.52	0.60	0.35	0.35	0.18	0.18
9	0.45	0.52	0.30	0.30	0.00	0.15
10	0.41	0.45	0.26	0.26	0.00	0.13
11	0.37	0.41	0.00	0.23	0.00	0.00
12	0.00	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

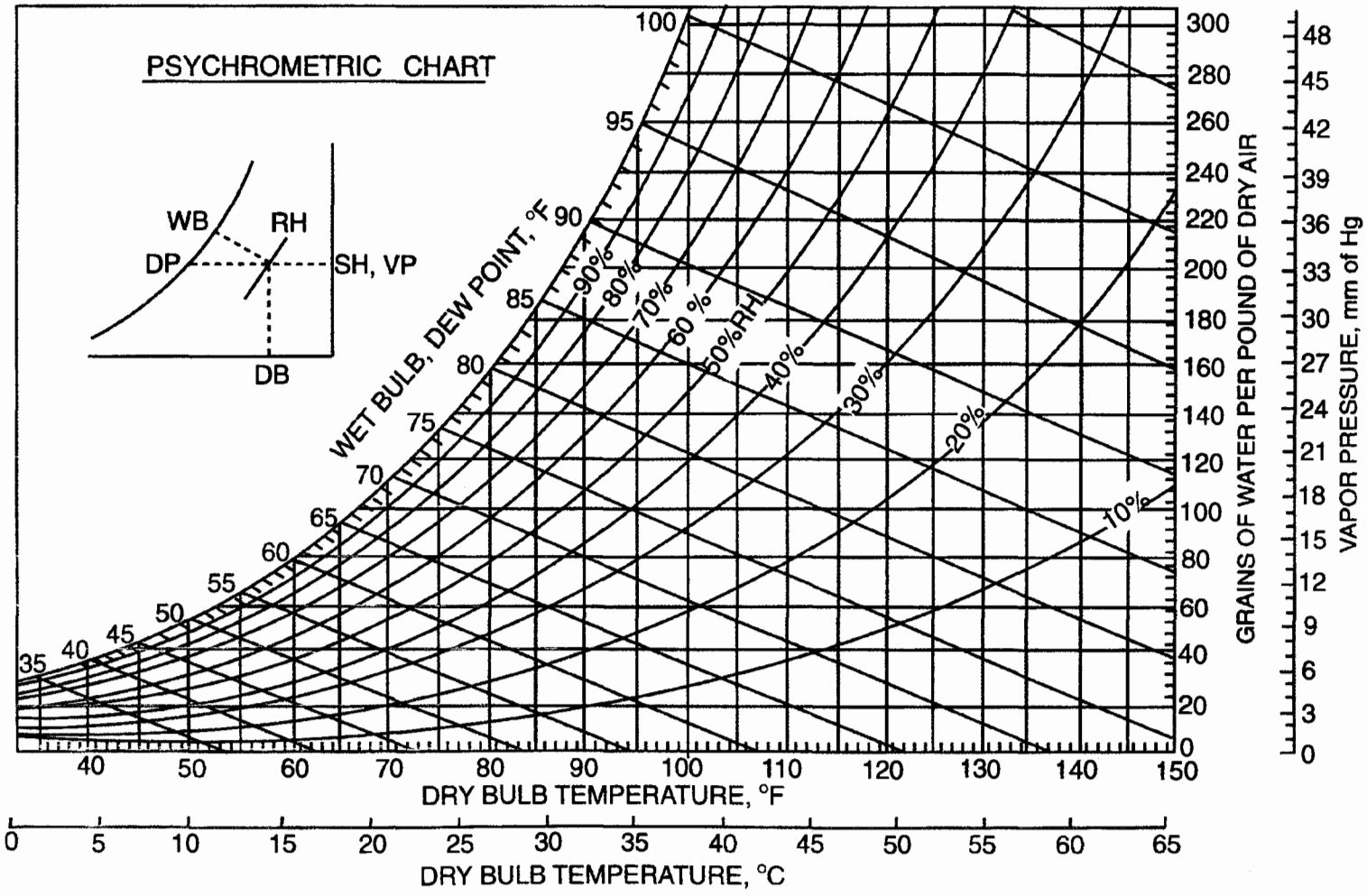
† Values of V are in inches

†† For lifting less frequently than once per 5 minutes, set F = 0.2 lifts/minute.

HEAT STRESS AND RELATIVE HUMIDITY

WBGT = 0.7 WB + 0.3 GT
(Indoors; no solar heat load)

WBGT = 0.7 WB + 0.2 GT + 0.1 DB
(Outdoors; with solar heat load)



CONCENTRATIONS OF VAPORS AND GASES

$$ppm = \frac{mg/m^3 \times 24.45}{MW}$$

$$TLV_m = \frac{1}{\left(\frac{f_1}{TLV_1} + \frac{f_2}{TLV_2} + \ldots + \frac{f_n}{TLV_n}\right)}$$

$$LFL_m = \frac{1}{\left(\frac{f_1}{LFL_1} + \frac{f_2}{LFL_2} + \ldots + \frac{f_n}{LFL_n}\right)}$$

VENTILATION

$$Q = AV \qquad V = 4005\sqrt{VP}$$

$$V = 4005\, C_e\sqrt{SP_h} \qquad TP = SP + VP$$

$$SP_{fan} = SP_{out} - SP_{in} - VP_{in}$$

$$SP_h = VP + h_e \qquad V = \frac{Q}{10x^2 + A}$$

$$h_e = \frac{(1 - C_e^2)VP}{C_e^2} \qquad C_e = \sqrt{\frac{VP}{SP_h}}$$

$$Q = \frac{403 \times 10^6 \times SG \times ER \times K}{MW \times C}$$

$$Q' = \frac{G}{C} \qquad \ln\left(\frac{G - Q'C_2}{G - Q'C_1}\right) = -\frac{Q'(t_2 - t_1)}{V}$$

$$C = \frac{G}{Q'}(1 - e^{-Nt/60}) \qquad C = \frac{P_v \times 10^6}{P_b}$$

$$\ln\left(\frac{C_2}{C_1}\right) = -\frac{Q'}{V}(t_2 - t_1)$$

GAS LAWS

$$PV = nRT$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Value of Gas Constant

			Absolute Pressure				
Volume	**Temp.**	**Moles**	atm	psi	mm Hg	in Hg	ft H_2O
ft^3	°K	gm	0.00290	0.0426	2.20	0.0867	0.0982
		lb	1.31	19.31	999.0	39.3	44.6
	°R	gm	0.00161	0.02366	1.22	0.0482	0.0546
		lb	0.730	10.73	555.0	21.8	24.8
liters	°K	gm	0.08205	1.206	62.4	2.45	2.78
		lb	37.2	547.0	28,300.0	1,113.0	1,262.0
	°R	gm	0.0456	0.670	34.6	1.36	1.55
		lb	20.7	304.0	15,700.0	619.0	701.0

RADIATION

(Ionizing)

$$I_2 = I_1 \frac{(d_1)^2}{(d_2)^2}$$

$$S \cong 6CE$$

$$I = I_0 e^{-\mu x}$$

$$I = \beta I_0 e^{-\mu x}$$

(Non-Ionizing)

$$W = \frac{16P}{\pi D^2} = \frac{4P}{A}$$

$$W = \frac{GP}{4\pi r^2} = \frac{AP}{\lambda^2 r^2}$$

$$E_{eff} = \Sigma E_\lambda S_\lambda \Delta_\lambda$$

$$c = \lambda f = \frac{\lambda}{T}$$

ENGINEERING ECONOMY

$$F = P(1+i)^n \qquad P = F(1+i)^{-n}$$

$$F = A\left(\frac{(1+i)^n - 1}{i}\right) \qquad A = F\left(\frac{i}{(1+i)^n - 1}\right)$$

$$P = A\left(\frac{(1+i)^n - 1}{i(1+i)^n}\right) \qquad A = P\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right)$$

RELIABILITY

$$P_f = 1 - R(t)$$

$$R(t) = e^{-\lambda t}$$

$$P_f = (1 - P_s)$$

NOISE

$$I = \frac{p}{\rho c} \qquad L_{pt} = 10 \log\left[\sum_{i=1}^{N} 10^{\left(L_{pi}/10\right)}\right]$$

$$L_w = 10 \log_{10} \frac{W}{W_0} \qquad L_p = 20 \log_{10} \frac{p}{p_0} \text{ dB}$$

$$T = \frac{8}{2^{[(L-90)/5]}} \qquad D = 100\left[\sum_{i=1}^{N} \frac{C_i}{T_i}\right]$$

$$dB_1 = dB_0 + 20 \log_{10}\left(\frac{d_0}{d_1}\right)$$

$$TWA = 16.61 \log_{10}\left[\frac{D}{100}\right] + 90$$

$$dB = 10 \log_{10}\left(\frac{A_2}{A_1}\right)$$

$$NR = \frac{12.6P\alpha^{1.4}}{A} \text{ dB / ft}$$

HEAT TRANSFER

$$H = \frac{Q}{\Delta t} = kA\left(\frac{T_1 - T_2}{L}\right)$$

HYDROSTATICS AND HYDRAULICS

$$p = \frac{F}{a} \qquad h_v = \frac{v^2}{2g}$$

$$h_p = \frac{p}{w} \qquad p_v = \frac{Q^2}{891 d^4}$$

$$Q_2 = Q_1\left[\frac{(S - R_2)^{0.54}}{(S - R_1)^{0.54}}\right] \qquad \frac{Q_1}{Q_2} = \frac{\sqrt{P_1}}{\sqrt{P_2}}$$

$$\frac{v_A^2}{2g} + \frac{p_A}{w} + z_A = \frac{v_B^2}{2g} + \frac{p_B}{w} + z_B + h_{AB}$$

$$P_d = \frac{4.52Q^{1.85}}{C^{1.85} d^{4.87}} \qquad P = (Q/K)^2$$

STATISTICS AND PROBABILITY

$$s = \sqrt{\frac{\sum(x^2)}{N-1}} \qquad (x = X - \bar{X}) \qquad \sigma = \sqrt{\frac{\sum(x^2)}{N}}$$

$$r = \frac{N\Sigma(xy) - (\Sigma x)(\Sigma y)}{\sqrt{[N\Sigma(x^2) - (\Sigma x)^2][N\Sigma(y^2) - (\Sigma y)^2]}}$$

$$x = X - \bar{X}$$
$$y = Y - \bar{Y}$$

$$r_s = 1 - \frac{6\Sigma(D^2)}{N(N^2-1)}$$

$$t = \frac{\bar{X} - \mu}{s}\sqrt{N-1} = \frac{\bar{X} - \mu}{\hat{s}}\sqrt{n}$$

$$z = \frac{\chi - \mu}{\sigma}$$

$$\chi^2 = \sum_{j=1}^{k} \frac{(o_j - e_j)^2}{e_j}$$

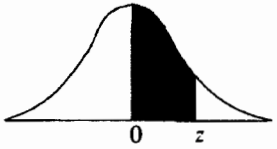
$$P_k^{\,n} = \frac{n!}{(n-k)!}$$

$$C_k^{\,n} = \frac{n!}{k!(n-k)!}$$

$$P(r) = \frac{(\lambda t)^r e^{-\lambda t}}{r!} = \frac{(t/m)^r e^{-t/m}}{r!}$$

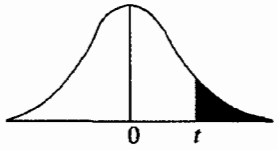
$$P_m = P\{X = m\} = \frac{a^m e^{-a}}{m!} \quad \text{where } a > 0,\ m = 0,1,2,\ldots$$

Areas Under the Standard Normal Curve from 0 to z



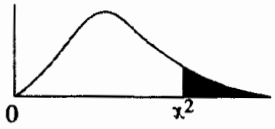
z	0	1	2	3	4	5	6	7	8	9
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0754
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2258	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2518	0.2549
0.7	0.2580	0.2621	0.2652	0.2673	0.2704	0.2736	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2996	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4937	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990

Table of Percentage Points of the t Distribution



df \ p	0.25	0.10	0.05	0.01
1	1.000	3.087	6.314	31.821
2	0.816	1.886	2.920	6.965
3	0.765	1.638	2.353	4.541
4	0.741	1.533	2.132	3.747
5	0.727	1.476	2.015	3.365
6	0.718	1.440	1.943	3.143
7	0.711	1.415	1.895	2.998
8	0.706	1.397	1.860	2.896
9	0.703	1.383	1.833	2.821
10	0.700	1.372	1.812	2.764
15	0.691	1.341	1.753	2.601
20	0.687	1.325	1.725	2.528
25	0.684	1.316	1.708	2.485
30	0.683	1.310	1.697	2.457
∞	0.674	1.282	1.645	2.326

Upper Percentage Points of the χ^2 Distribution



df \ p	0.99	0.95	0.90	0.10	0.05	0.01
1	0.0002	0.0039	0.0158	2.706	3.841	6.635
2	0.0201	0.103	0.211	4.605	5.991	9.210
3	0.115	0.352	0.584	6.251	7.815	11.345
4	0.297	0.711	1.064	7.779	9.488	13.277
5	0.554	1.145	1.610	9.236	11.070	15.086
6	0.872	1.635	2.204	10.645	12.592	16.812
7	1.239	2.167	2.833	12.017	14.067	18.475
8	1.646	2.733	3.490	13.362	15.507	20.090
9	2.088	3.325	4.168	14.684	16.919	21.666
10	2.558	3.940	4.865	15.987	18.307	23.209
11	3.503	4.575	5.578	17.275	19.675	24.725
12	3.571	5.226	6.304	18.549	21.026	26.217
13	4.107	5.892	7.042	19.812	22.362	27.688
14	4.660	6.571	7.790	21.064	23.685	29.141
15	5.229	7.261	8.547	22.307	24.996	30.578
20	8.260	10.851	12.443	28.412	31.410	37.566
25	11.524	14.611	16.473	34.382	37.652	44.314
30	14.953	18.493	20.599	40.256	43.773	50.892